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An Injector to the 33 MHz 4-rod RFQ

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An ion injector has been designed and assembled for the 33 MHz 4-rod RFQ linac.[1] This injector comprises of a Freeman type ion source, a 90 degree analyzing magnet, and magnetic quadrupole lenses. An emittance measurement gear and a Faraday cup are also installed between the injector and the RFQ. Beam optics calculation is done up to the second order using TRANSPORT[2] and the results are reflected in the design of the magnetic optical components.

KEY WORDS: RFQ/ 4-ROD RFQ/ Ion Injector/

1. BEAM OPTICS

Beam optics calculation is done first using TRACE-3D.[3] An ion beam of 30 keV single-charged boron is followed through the optical elements. Calculations are done interactively to find the match to the RFQ. The results are recalculated and checked to the second order by TRANSPORT. The one of the most important assumptions in the optics calculation is that the ion beam is 100% neutralized by electrons which reside in the beam. So there is no space-charge force and beam current can be set to zero in those calculations.

A summary of the beam optics calculation is shown in table 1. The ion beam is extracted from the rectangular slit of a Freeman source. This is to attain higher mass resolution without reducing the beam current. At the entrance of the RFQ, the ion beam is focused into a near round shape to match to the RFQ. An einzel lens has to be added just upstream of the RFQ entrance to get the mismatch factor - as defined in TRACE-3D - below 0.1.

The results of the second order calculations on TRANSPORT indicates the degradation of the beam. The emittance growth and the shift of the beam phase-space centroids cannot be neglected if we were to achieve beam transmission to theoretical limit. The corrections are made to the analyzing magnet by including sextupole components.[4] The results are very satisfactory as can be seen in table 1 : there is virtually no increase in the beam sizes, the degradation in the beam divergences become below 0.4%, and the shifts of the beam phase-space centroids to permissible level.

2. COMPONENTS AND LAYOUT

Figure 1 is a schematic layout of and photo. 1 is an exterior view of the RFQ linac accelerator system as installed in the accelerator laboratory, ICR, Kyoto University. The injector

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Table 1

	Horizontal	Vertical	
Beam paramenters at the source:			
Emittance (π mm mrad)	50	75	
α (unit less)	0.0	0.0	
β (mm/mrad)	0.0558	0.75	
1/2 beam size (mm)	1.67	7.5	
1/2 beam divergence (mrad)	30	10	
	1st order	2nd order w/o correction	2nd order with correction
Beam parameters at the RFQ entrance:			
Horizontal			
1/2 beam size (mm)	2.62	2.83 (0.995)	2.62 (−0.004)
1/2 beam divergence (mrad)	27.4	29.3 (−7.16)	27.5 (−0.816)
Vertical			
1/2 beam size (mm)	2.62	2.83 (−0.995)	2.62 (0.004)
1/2 beam divergence (mrad)	27.4	29.3 (7.16)	27.5 (0.816)

Note: Numbers in parenthesis are shifts of beam centroids.

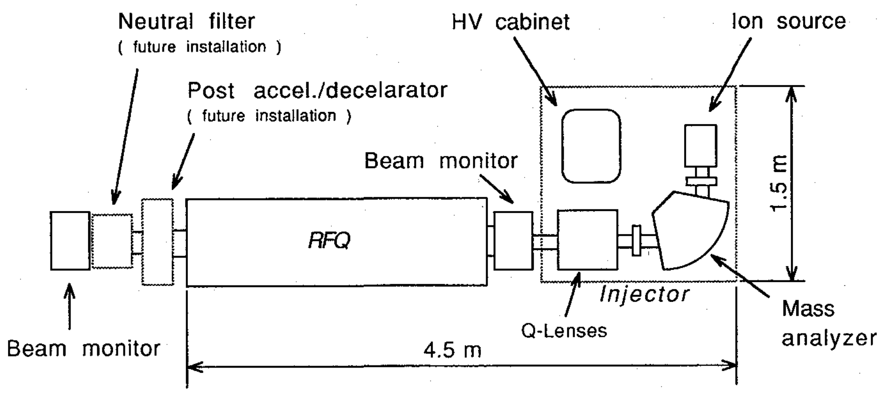

Fig. 1. Schematic layout of injector and RFQ as installed in Accelerator Laboratory, ICR, Kyoto University.

comprises of a Freeman ion source, a 90 degree analyzing magnet, quadrupole magnets, and a HV cabinet in which a mass flow controller system and ion source power supplies are installed. The vacuum system comprises of a 550 liter/sec. turbo molecular pump and a 350 liter/min. oil rotary pump. All those beam optical, electrical, and vacuum components are arranged and installed in the X-ray shielded cabinet. Photo. 2 is a picture of the injector taken from the ion source side. Compactness and easy maintainability is sought in the design of the injector. The descriptions of the components are as follows:

Ion source

A Freeman type "medium-current" ion source frequently used in industry is adopted.[5] This ion source delivers a mA class single-charged boron ion beam at 30 keV extraction voltage.

Analyzer magnet

The bend angle is 90 degree and the mass resolution is more than 100. The sextupole

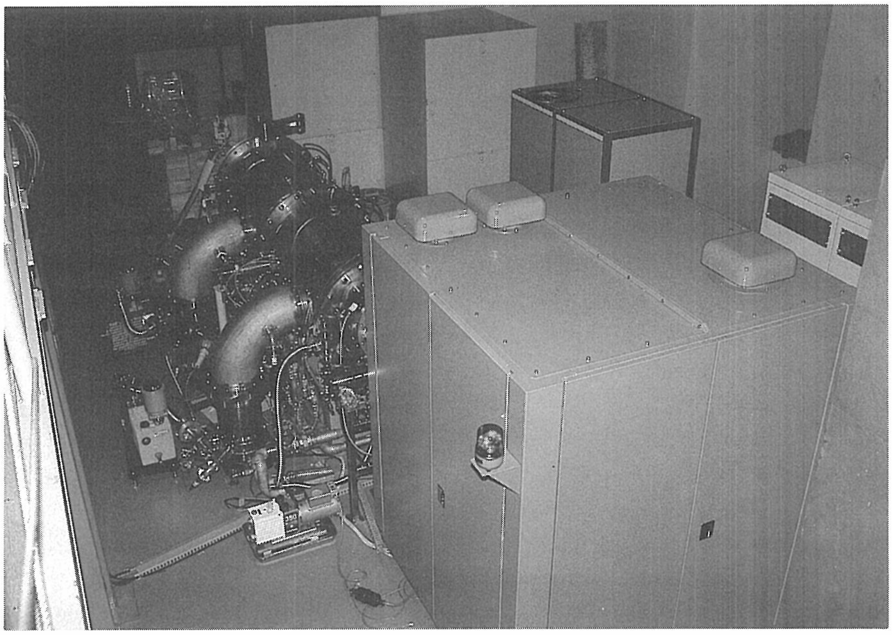

Photo. 1.   Exterior view of injector and RFQ linac.

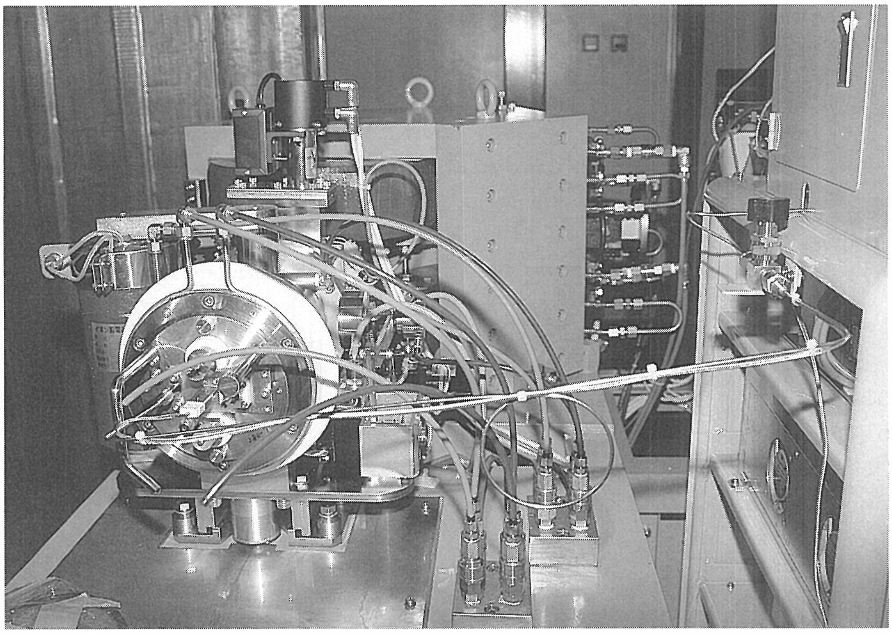

Photo. 2.   Interior view of injector from the ion source side.

corrections are made to improve the beam quality. The magnet has rotatable entrance and exit pole pieces for the fine correction of the beam optics. The magnetic boundary is approximately that of Rogowski type.[6,7] Magnet design are done using computer codes, POISSON and PANDIRA.[8]

Quadrupole magnets

There are four quadrupole magnets, which are all identical in construction. The sextupole components of magnetic field are minimized in the design. The magnet coils are vacuum impregnated with epoxy resin that has high thermal conductivity and they are indirectly cooled by water. The temperature stability of the coils is greatly improved in this design - the temperature rise is only 5°C with 1.8 liter/min cooling water in the 220 turn coil at the current of 20 A . The field gradient of 17 T/m is attainable at this current and it is more than adequate in our requirement.

Beam monitor

Beam emittance and beam intensity can be measured in this monitor. The emittance measurement gear is that of "two-slit method".[9] Two sets of probe are positioned in such a way that they scan orthogonally in the transverse plane of the beam optic axis. The Faraday cup has aperture diameter of 30 mm. The ratio of the aperture to length of the cup is about three.

Ion source controller and beam controller

All the setup and adjustments of the injector can be done from a remote control room located about 15 m south of the experimental room where the RFQ linac system is installed. The ion source controller basically comprises of a human interface I/O panel and a programmable controller both integrated into the existing vacuum control system via optical fiber network. The beam controller from which one can control the strengths of the analyzer magnet, of the quadrupole lenses, of the einzel lens, and also the emittance monitor is based on a personal computer with GP-IB communication link capability.

7. CONCLUDING REMARKS

An ion injector has been designed and constructed. The key factors in the design are beam quality, compactness, and easy maintainability. It was not easy task in real life to get 100 % satisfaction in all the three criterion, however, we are happy that our goal is mostly realized in a relatively short period. The next step of this project is to accelerate a beam!

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